GENERAL PRINCIPLES

CHAPTER OBJECTIVES

■ To provide an introduction to the basic quantities and idealizations of mechanics.

■ To state Newton's Laws of Motion and Gravitation.

■ To review the principles for applying the SI system of units.

■ To examine the standard procedures for performing numerical calculations.

■ To present a general guide for solving problems.

1.1 MECHANICS

Mechanics is a branch of the physical sciences that is concerned with the state of rest or motion of bodies that are subjected to the action of forces. In general, this subject can be subdivided into three branches: *rigid-body mechanics, deformable-body mechanics*, and *fluid mechanics*. In this book we will study rigid-body mechanics since it is a basic requirement for the study of the mechanics of deformable bodies and the mechanics of fluids. Furthermore, rigid-body mechanics is essential for the design and analysis of many types of structural members, mechanical components, or electrical devices encountered in engineering.

Rigid-body mechanics is divided into two areas: statics and dynamics. *Statics* deals with the equilibrium of bodies, that is, those that are either at rest or move with a constant velocity; whereas *dynamics* is concerned with the accelerated motion of bodies. We can consider statics as a special case of dynamics, in which the acceleration is zero; however, statics deserves separate treatment in engineering education since many objects are designed with the intention that they remain in equilibrium.

Historical Development.   The subject of statics developed at a very early time because its principles can be formulated simply from measurements of geometry and force. For example, the writings of Archimedes (287–212 B.C.) deal with the principle of the lever. Studies of the pulley, inclined plane, and wrench are also recorded in ancient writings—at times when the requirements for engineering were limited primarily to building construction.

Since the principles of dynamics depend on an accurate measurement of time, this subject developed much later. Galileo Galilei (1564–1642) was one of the first major contributors to this field. His work consisted of experiments using pendulums and falling bodies. The most significant contributions in dynamics, however, were made by Isaac Newton (1642–1727), who is noted for his formulation of the three fundamental laws of motion and the law of universal gravitational attraction. Shortly after these laws were postulated, important techniques for their application were developed by other scientists and engineers, some of whom will be mentioned throughout the book.

1.2   FUNDAMENTAL CONCEPTS

Before we begin our study of engineering mechanics, it is important to understand the meaning of certain fundamental concepts and principles.

Basic Quantities.   The following four quantities are used throughout mechanics.

Length.   *Length* is used to locate the position of a point in space and thereby describe the size of a physical system. Once a standard unit of length is defined, one can then use it to define distances and geometric properties of a body as multiples of this unit.

Time.   *Time* is conceived as a succession of events. Although the principles of statics are time independent, this quantity plays an important role in the study of dynamics.

Mass.   *Mass* is a measure of a quantity of matter that is used to compare the action of one body with that of another. This property manifests itself as a gravitational attraction between two bodies and provides a measure of the resistance of matter to a change in velocity.

Force.   In general, *force* is considered as a "push" or "pull" exerted by one body on another. This interaction can occur when there is direct contact between the bodies, such as a person pushing on a wall, or it can occur through a distance when the bodies are physically separated. Examples of the latter type include gravitational, electrical, and magnetic forces. In any case, a force is completely characterized by its magnitude, direction, and point of application.

Idealizations. Models or idealizations are used in mechanics in order to simplify application of the theory. Here we will consider three important idealizations.

Particle. A *particle* has a mass, but a size that can be neglected. For example, the size of the earth is insignificant compared to the size of its orbit, and therefore the earth can be modeled as a particle when studying its orbital motion. When a body is idealized as a particle, the principles of mechanics reduce to a rather simplified form since the geometry of the body *will not be involved* in the analysis of the problem.

Rigid Body. A *rigid body* can be considered as a combination of a large number of particles in which all the particles remain at a fixed distance from one another, both before and after applying a load. This model is important because the body's shape does not change when a load is applied, and so we do not have to consider the type of material from which the body is made. In most cases the actual deformations occurring in structures, machines, mechanisms, and the like are relatively small, and the rigid-body assumption is suitable for analysis.

Concentrated Force. A *concentrated force* represents the effect of a loading which is assumed to act at a point on a body. We can represent a load by a concentrated force, provided the area over which the load is applied is very small compared to the overall size of the body. An example would be the contact force between a wheel and the ground.

Three forces act on the ring. Since these forces all meet at a point, then for any force analysis, we can assume the ring to be represented as a particle.

Steel is a common engineering material that does not deform very much under load. Therefore, we can consider this railroad wheel to be a rigid body acted upon by the concentrated force of the rail.

Newton's Three Laws of Motion.   Engineering mechanics is formulated on the basis of Newton's three laws of motion, the validity of which is based on experimental observation. These laws apply to the motion of a particle as measured from a *nonaccelerating* reference frame. They may be briefly stated as follows.

First Law. A particle originally at rest, or moving in a straight line with constant velocity, tends to remain in this equilibrium state provided the particle is *not* subjected to an unbalanced force, Fig. 1–1a.


Equilibrium

(a)
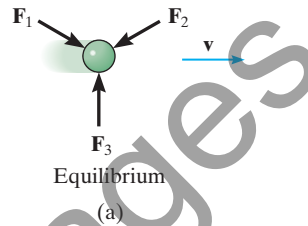
Second Law. A particle acted upon by an *unbalanced force* **F** experiences an acceleration **a** that has the same direction as the force and a magnitude that is directly proportional to the force, Fig. 1–1b.[*] If the particle has a mass m, this law may be expressed mathematically as

$$\mathbf{F} = m\mathbf{a} \qquad\qquad (1\text{--}1)$$

Accelerated motion

(b)
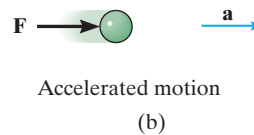
Third Law. The mutual forces of action and reaction between two particles are equal, opposite, and collinear, Fig. 1–1c.

Action–reaction

(c)
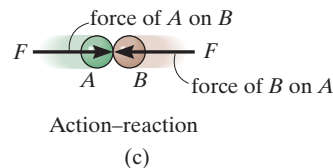
Fig. 1–1

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[*]Stated another way, the unbalanced force acting on the particle is proportional to the time rate of change of the particle's linear momentum.

Newton's Law of Gravitational Attraction.   Shortly after formulating his three laws of motion, Newton postulated a law governing the gravitational attraction between any two particles. Stated mathematically,

$$F = G\frac{m_1 m_2}{r^2} \tag{1–2}$$

where

F = force of gravitation between the two particles

G = universal constant of gravitation; according to experimental evidence, $G = 66.73(10^{-12})\ \text{m}^3/(\text{kg}\cdot\text{s}^2)$

m_1, m_2 = mass of each of the two particles

r = distance between the two particles

Weight.   According to Eq. 1–2, any two particles or bodies have a mutual attractive (gravitational) force acting between them. In the case of a particle located at or near the surface of the earth, however, the only gravitational force having any sizable magnitude is that between the earth, because of its very large mass, and the particle. Consequently, this force, called the *weight*, will be the only gravitational force we will consider.

From Eq. 1–2, if the particle has a mass $m_1 = m$, and we assume the earth is a nonrotating sphere of constant density and having a mass $m_2 = M_e$, then if r is the distance between the earth's center and the particle, the weight W of the particle becomes

$$W = G\frac{mM_e}{r^2}$$

If we let $g = GM_e/r^2$, we have

$$\boxed{W = mg} \tag{1–3}$$

If we allow the particle to fall downward, then neglecting air resistance, the only force acting on the particle is its weight, and so Eq. 1–1 becomes $W = ma$. Comparing this result with Eq. 1–3, we see that $a = g$. In other words, g is the acceleration due to gravity. Since it depends on r, then the weight of the particle or body is *not* an absolute quantity. Instead, its magnitude depends upon the elevation where the measurement was made. For most engineering calculations, however, g is determined at sea level and at a latitude of 45°, which is considered the "standard location."

The astronaut's weight is diminished since she is far removed from the gravitational field of the earth.

Refer to the companion website for Lecture Summary and Quiz videos.

1.3   THE INTERNATIONAL SYSTEM OF UNITS

The four basic quantities—length, time, mass, and force—are not all independent from one another; in fact, they are *related* by Newton's second law of motion, $\mathbf{F} = m\mathbf{a}$. Because of this, the *units* used to measure these quantities cannot *all* be selected arbitrarily. The equality $\mathbf{F} = m\mathbf{a}$ is maintained only if three of the four units, called *base units*, are *defined* and the fourth unit is then *derived* from the equation.
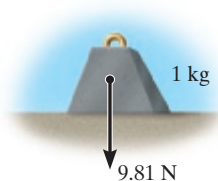
Fig. 1-2

1 kg

9.81 N

The International System of units, abbreviated SI after the French *Système International d'Unités*, is a modern version of the metric system which has received worldwide recognition. As shown in Table 1–1, the system defines length in meters (m), time in seconds (s), and mass in kilograms (kg).[†] The unit of force, called a **newton** (N), is *derived* from $\mathbf{F} = m\mathbf{a}$. Thus, 1 newton is equal to a force required to give 1 kilogram of mass an acceleration of 1 m/s^2 $(\text{N} = \text{kg} \cdot \text{m/s}^2)$. Think of this force as the weight of a small apple.

If the weight of a body located at the "standard location" is to be determined in newtons, then Eq. 1–3 must be applied. Here measurements give $g = 9.806\,65 \text{ m/s}^2$; however, for calculations, the value $g = 9.81 \text{ m/s}^2$ will be used. Thus,

$$W = mg \qquad (g = 9.81 \text{ m/s}^2) \qquad\qquad (1\text{–}4)$$

Therefore, a body of mass 1 kg has a weight of 9.81 N, a 2-kg body weighs 19.62 N, and so on, Fig. 1–2.

TABLE 1–1 International System of Units				
Quantity	Length	Time	Mass	Force
SI Units	meter	second	kilogram	newton*
	m	s	kg	N $\left(\dfrac{\text{kg} \cdot \text{m}}{\text{s}^2}\right)$

*Derived unit.

Prefixes.   When a numerical quantity is either very large or very small, the SI units used to define its size may be modified by using a prefix. Some of these prefixes used are shown in Table 1–2. Each represents a multiple or submultiple of a unit which, if applied successively, moves the decimal point of a numerical quantity to every third place.[‡] For example, 4 000 000 N = 4 000 kN (kilo-newton) = 4 MN (mega-newton), or 0.005 m = 5 mm (milli-meter). Notice that the SI system does not include the multiple deca (10) or the submultiple centi (0.01), which form part of the metric system. Except for some volume and area measurements, the use of these prefixes is generally avoided in science and engineering.

[†]Historically, the meter was defined as 1/10,000,000 the distance from the Equator to the North Pole, and the kilogram is 1/1000 of a cubic meter of water.
[‡]The kilogram is the only base unit that is defined with a prefix.

TABLE 1–2 Prefixes			
	Exponential Form	Prefix	SI Symbol
Multiple			
1 000 000 000	10^9	giga	G
1 000 000	10^6	mega	M
1 000	10^3	kilo	k
Submultiple			
0.001	10^{-3}	milli	m
0.000 001	10^{-6}	micro	μ
0.000 000 001	10^{-9}	nano	n

Rules for Use.   Here are a few of the important rules that describe the proper use of the various SI symbols:

- Quantities defined by several units which are multiples of one another are separated by a *dot* to avoid confusion with prefix notation, as indicated by $N = kg \cdot m/s^2 = kg \cdot m \cdot s^{-2}$. Also, $m \cdot s$ (meter-second), whereas ms (milli-second).

- The exponential power on a unit having a prefix refers to both the unit *and* its prefix. For example, $\mu N^2 = (\mu N)^2 = \mu N \cdot \mu N$. Likewise, mm^2 represents $(mm)^2 = mm \cdot mm$.

- With the exception of the base unit the kilogram, in general avoid the use of a prefix in the denominator of composite units. For example, do not write N/mm, but rather kN/m; also, m/mg should be written as Mm/kg.

- When performing calculations, represent the numbers in terms of their *base or derived units* by converting all prefixes to powers of 10. The final result should then be expressed using a *single prefix*. Also, after calculation, it is best to keep numerical values between 0.1 and 1000; otherwise, a suitable prefix should be chosen. For example,

$$(50 \text{ kN})(60 \text{ nm}) = \left[50(10^3) \text{ N} \right] \left[60(10^{-9}) \text{ m} \right]$$
$$= 3000(10^{-6}) \text{ N} \cdot \text{m} = 3(10^{-3}) \text{ N} \cdot \text{m} = 3 \text{ mN} \cdot \text{m}$$

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1.4   NUMERICAL CALCULATIONS

Numerical work in engineering practice is most often performed by using handheld calculators and computers. It is important, however, that the answers to any problem be reported with justifiable accuracy using appropriate significant figures. In this section we will discuss these topics together with some other important aspects involved in all engineering calculations.

Dimensional Homogeneity.   The terms of any equation used to describe a physical process must be *dimensionally homogeneous*; that is, each term must be expressed in the same units. Provided this is the case, all the terms of an equation can then be combined if numerical values are substituted for the variables. Consider, for example, the equation $s = vt + \frac{1}{2}at^2$, where, in SI units, s is the position in meters, m, t is time in seconds, s, v is velocity in m/s and a is acceleration in m/s^2. Regardless of how this equation is evaluated, it maintains its dimensional homogeneity. In the form stated, each of the three terms is expressed in meters $\left[\text{m}, (\text{m}/\text{s})\text{s}, (\text{m}/\text{s}^2)\text{s}^2\right]$ or solving for a, $a = 2s/t^2 - 2v/t$, the terms are each expressed in units of m/s^2 $\left[\text{m}/\text{s}^2, \text{m}/\text{s}^2, (\text{m}/\text{s})/\text{s}\right]$.

Keep in mind that problems in mechanics always involve the solution of dimensionally homogeneous equations, and so this fact can then be used as a partial check for algebraic manipulations of an equation.

Significant Figures.   The number of significant figures contained in any number determines the accuracy of the number. For instance, the number 4981 contains four significant figures. However, if zeros occur at the end of a whole number, it may be unclear as to how many significant figures the number represents. For example, 23 400 might have three (234), four (2340), or five (23 400) significant figures. To avoid these ambiguities, we will use *engineering notation* to report a result. This requires that numbers be rounded off to the appropriate number of significant digits and then expressed in multiples of (10^3), such as (10^3), (10^6), or (10^{-9}). For instance, if 23 400 has five significant figures, it is written as $23.400(10^3)$, but if it has only three significant figures, it is written as $23.4(10^3)$.

   If zeros occur at the beginning of a number that is less than one, then the zeros are not significant. For example, 0.008 21 has three significant figures. Using engineering notation, this number is expressed as $8.21(10^{-3})$. Likewise, 0.000 582 can be expressed as $0.582(10^{-3})$ or $582(10^{-6})$.

Rounding Off Numbers.

Rounding off a number is necessary so that the accuracy of the result will be the same as that of the problem data. As a general rule, any numerical figure ending in a number greater than five is rounded up and a number less than five is not rounded up. The rules for rounding off numbers are best illustrated by examples. Suppose the number 3.5587 is to be rounded off to *three* significant figures. Because the fourth digit (8) is *greater than* 5, the third number is rounded up to 3.56. Likewise 0.5896 becomes 0.590 and 9.3866 becomes 9.39. If we round off 1.341 to three significant figures, because the fourth digit (1) is *less than* 5, then we get 1.34. Likewise 0.3762 becomes 0.376 and 9.871 becomes 9.87. There is a special case for any number that ends in a 5. As a general rule, if the digit preceding the 5 is an *even number*, then this digit is *not* rounded up. If the digit preceding the 5 is an *odd number*, then it is rounded up. For example, 75.25 rounded off to three significant digits becomes 75.2, 0.1275 becomes 0.128, and 0.2555 becomes 0.256.

Calculations.

When a sequence of calculations is performed, it is best to store the intermediate results in the calculator. In other words, do not round off calculations until expressing the final result. This procedure maintains precision throughout the series of steps to the final solution. In this book we will generally round off the answers to *three significant figures* since most of the data in engineering mechanics, such as geometry and loads, may be reliably measured to this accuracy.

When solving problems, do the work as neatly as possible. Being neat will stimulate clear and orderly thinking, and vice versa.

1.5 GENERAL PROCEDURE FOR ANALYSIS

Attending a lecture, reading this book, and studying the example problems helps, but **the most effective way of learning the principles of engineering mechanics is to *solve problems***. To be successful at this, it is important to always present the work in a *logical* and *orderly manner*, as suggested by the following sequence of steps:

- Read the problem carefully and try to correlate the actual physical situation with the theory studied.
- Tabulate the problem data and *draw to a large scale* any necessary diagrams.
- Apply the relevant principles, generally in mathematical form. When writing any equations, be sure they are dimensionally homogeneous.
- Solve the necessary equations, and report the answer with no more than three significant figures.
- Study the answer with technical judgment and common sense to determine whether or not it seems reasonable.

IMPORTANT POINTS

- Statics is the study of bodies that are at rest or move with constant velocity.
- A particle has a mass but a size that can be neglected, and a rigid body does not deform under load.
- A force is considered as a "push" or "pull" of one body on another.
- Concentrated forces are assumed to act at a point on a body.
- Newton's three laws of motion should be memorized.
- Mass is measure of a quantity of matter that does not change from one location to another. Weight refers to the gravitational attraction of the earth on a body or quantity of mass. Its magnitude depends upon the elevation at which the mass is located.
- In the SI system the unit of force, the newton, is a derived unit. The meter, second, and kilogram are base units.
- Prefixes G, M, k, m, μ, and n are used to represent large and small numerical quantities. Their exponential size should be known, along with the rules for using the SI units.
- Perform numerical calculations with several significant figures, and then report the final answer to three significant figures.
- Algebraic manipulations of an equation can be checked in part by verifying that the equation remains dimensionally homogeneous.
- Know the rules for rounding off numbers.

Refer to the companion website for Lecture Summary and Quiz videos.

EXAMPLE   1.1

Convert 100 km/h to m/s and 24 m/s to km/h.

SOLUTION
Since 1 km = 1000 m and 1 h = 3600 s, the factors of conversion are arranged in the following order, so that a cancellation of the units can be applied:

$$100 \text{ km/h} = \frac{100 \text{ km}}{\text{h}}\left(\frac{1000 \text{ m}}{\text{km}}\right)\left(\frac{1 \text{ h}}{3600 \text{ s}}\right)$$

$$= \frac{100(10^3) \text{ m}}{3600 \text{ s}} = 27.8 \text{ m/s} \qquad \textit{Ans.}$$

$$24 \text{ m/s} = \left(\frac{24 \text{ m}}{\text{s}}\right)\left(\frac{1 \text{ km}}{1000 \text{ m}}\right)\left(\frac{3600 \text{ s}}{1 \text{ h}}\right)$$

$$= \frac{86.4 \ (10^3) \text{ km}}{1000 \text{ h}} = 86.4 \text{ km/h} \qquad \textit{Ans.}$$

Note: Remember to round off the final answer to three significant figures.

EXAMPLE   1.2

Convert the density of steel 7.85 g/cm^3 to kg/m^3.

SOLUTION
Using 1 kg = 1000 g and 1 m = 100 cm, and arrange the conversion factor in such a way that g and cm^3 can be canceled out.

$$7.85 \text{ g/cm}^3 = \left(\frac{7.85 \text{ g}}{\text{cm}^3}\right)\left(\frac{1 \text{ kg}}{1000 \text{ g}}\right)\left(\frac{100 \text{ cm}}{1 \text{ m}}\right)^3$$

$$= \left(\frac{7.85 \text{ g}}{\text{cm}^3}\right)\left(\frac{1 \text{ kg}}{1000 \text{ g}}\right)\left(\frac{100^3 \text{ cm}^3}{1 \text{ m}^3}\right)$$

$$= 7.85(10^3) \text{ kg/m}^3 \qquad \textit{Ans.}$$

1

EXAMPLE 1.3

Evaluate each of the following and express with SI units having an appropriate prefix: (a) (50 mN)(6 GN), (b) (400 mm)(0.6 MN)^2, (c) 45 MN^3/900 Gg.

SOLUTION

First convert each number to base units, perform the indicated operations, then choose an appropriate prefix.

Part (a)

$$(50 \text{ mN})(6 \text{ GN}) = \left[50\left(10^{-3}\right) \text{ N}\right]\left[6\left(10^9\right) \text{ N}\right]$$

$$= 300\left(10^6\right) \text{ N}^2$$

$$= 300\left(10^6\right) \text{ N}^2\left(\frac{1 \text{ kN}}{10^3 \text{ N}}\right)\left(\frac{1 \text{ kN}}{10^3 \text{ N}}\right)$$

$$= 300 \text{ kN}^2 \qquad\qquad Ans.$$

Note: Keep in mind the convention kN^2 = (kN)^2 = 10^6 N^2.

Part (b)

$$(400 \text{ mm})(0.6 \text{ MN})^2 = \left[400\left(10^{-3}\right) \text{ m}\right]\left[0.6\left(10^6\right) \text{ N}\right]^2$$

$$= \left[400\left(10^{-3}\right) \text{ m}\right]\left[0.36\left(10^{12}\right) \text{ N}^2\right]$$

$$= 144\left(10^9\right) \text{ m} \cdot \text{N}^2$$

$$= 144 \text{ Gm} \cdot \text{N}^2 \qquad\qquad Ans.$$

We can also write

$$144\left(10^9\right) \text{ m} \cdot \text{N}^2 = 144\left(10^9\right) \text{ m} \cdot \text{N}^2\left(\frac{1 \text{ MN}}{10^6 \text{ N}}\right)\left(\frac{1 \text{ MN}}{10^6 \text{ N}}\right)$$

$$= 0.144 \text{ m} \cdot \text{MN}^2 \qquad\qquad Ans.$$

Part (c)

$$\frac{45 \text{ MN}^3}{900 \text{ Gg}} = \frac{45\left(10^6 \text{ N}\right)^3}{900\left(10^6\right) \text{ kg}}$$

$$= 50\left(10^9\right) \text{ N}^3/\text{kg}$$

$$= 50\left(10^9\right) \text{ N}^3\left(\frac{1 \text{ kN}}{10^3 \text{ N}}\right)^3\frac{1}{\text{kg}}$$

$$= 50 \text{ kN}^3/\text{kg} \qquad\qquad Ans.$$

Sample pages

PROBLEMS

The answers to all but every fourth problem (asterisk) are given in the back of the book.

1–1. Round off the following numbers to three significant figures: (a) 58 342 m, (b) 68.534 s, (c) 2553 N, (d) 7555 kg.

1–2. Represent each of the following combinations of units in the correct SI form using an appropriate prefix: (a) Mg/mm, (b) mN /μs, (c) μm · Mg.

1–3. Represent each of the following combinations of units in the correct SI form using an appropriate prefix: (a) kN/μs, (b) Mg/mN, (c) MN/(kg · ms).

*1–4. Determine the mass of an object that has a weight of (a) 20 mN, (b) 150 kN, (c) 60 MN. Express the answer to three significant figures.

1–5. Round off the following numbers to three significant figures: (a) 3.455 55 m, (b) 45.556 s, (c) 5555 N, (d) 4525 kg.

1–6. Represent each of the following as a number between 0.1 and 1000 using an appropriate prefix: (a) 45 320 kN, (b) 568(10^5) mm, (c) 0.005 63 mg.

1–7. Represent each of the following combinations of units in the correct SI form: (a) Mg/ms, (b) N/mm, (c) mN/(kg · μs).

*1–8. Represent each of the following quantities in the correct SI form using an appropriate prefix: (a) 0.000 431 kg, (b) 35.3(10^3) N, (c) 0.005 32 km.

1–9. Represent each of the following combinations of units in the correct SI form using an appropriate prefix: (a) μMN, (b) N/μm, (c) MN/ks^2, (d) kN/ms.

1–10. Represent each of the following combinations of units in the correct SI form using an appropriate prefix: (a) m/ms, (b) μkm, (c) ks/mg, (d) km · μN.

1–11. Represent each of the following combinations of units in the correct SI form using an appropriate prefix: (a) GN · μm, (b) kg/μm, (c) N/ks^2, (d) kN/μs.

*1–12. A rocket has a mass 3.529(10^6) kg on earth. Specify (a) its mass in SI units, and (b) its weight in SI units. If the rocket is on the moon, where the acceleration due to gravity is $g_m = 1.61$ m/s^2, determine to three significant figures (c) its weight in SI units, and (d) its mass in SI units.

1–13. Using the SI system of units, show that Eq. 1–2 is a dimensionally homogeneous equation which gives F in newtons. Determine to three significant figures the gravitational force acting between two spheres that are touching each other. The mass of each sphere is 200 kg and the radius is 300 mm.

1–14. Evaluate each of the following and express with an appropriate prefix: (a) (430 kg)^2, (b) (0.002 mg)^2, and (c) (230 m)^3.

1–15. Evaluate each of the following to three significant figures and express each answer in SI units using an appropriate prefix: (a) (200 kN)^2, (b) (0.005 mm)^2, (c) (400 m)^3.

*1–16. Evaluate each of the following to three significant figures and express each answer in SI units using an appropriate prefix: (a) (212 mN)^2, (b) (52 800 ms)^2, (c) $[548(10^6)]^{1/2}$ ms.

1–17. Evaluate (204 mm)(0.004 57 kg)/(34.6 N) to three significant figures and express the answer in SI units using an appropriate prefix.

1–18. What is the weight in newtons of an object that has a mass of (a) 8 kg, (b) 0.04 g, (c) 760 Mg?

1–19. A concrete column has a diameter of 350 mm and a length of 2 m. If the density (mass/volume) of concrete is 2.45 Mg/m^3, determine the weight of the column.

*1–20. Two particles have a mass of 8 kg and 12 kg, respectively. If they are 800 mm apart, determine the force of gravity acting between them. Compare this result with the weight of each particle.

1–21. If a man weighs 690 newtons on earth, specify (a) his mass in kilograms. If the man is on the moon, where the acceleration due to gravity is $g_m = 1.61$ m/s^2, determine (b) his weight in newtons, and (c) his mass in kilograms.